Blockchain-based applications in various areas of healthcare functioning

(Aplikacje wykorzystujące technologię *blockchain* w różnych dziedzinach funkcjonowania opieki zdrowotnej)

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Abstract – Introduction. Blockchain technology can be a breakthrough support for healthcare applications (systems).
The purpose of the work. The aim of the study was to discuss proposals for solutions and examples of blockchain applications at different levels of health care, as well as examples of national solutions using "blockchain chains" technology.
The aim of the study. The aim of the study was to discuss proposals and examples of blockchain applications at different levels of health care, as well as examples of national solutions using "blockchain chains" technology.
Selection of material. The search was conducted in the Scopus database using the terms blockchain, health care 2017-2019. The literature found in the Google Scholar database was analyzed in terms of the highest number of citations. Such selected literature was used as a material for the preparation of the present paper.
Conclusions. Trends in research on health care block chains indicate that they are mainly used for data exchange, health records and access control, less so for supply chain management or drug distribution management.

Key words **–** blockchain, information system, healthcare.

Streszczenie – Wstęp. Technologia *blockchain* może być przełomowym wsparciem wykorzystywanym w aplikacjach (systemach) opieki zdrowotnej.
Cel pracy. Celem pracy było omówienie propozycji rozwiązań i przykłady zastosowań *blockchain* na różnych poziomach ochrony zdrowia, a także przykłady rozwiązań krajowych wykorzystujących technologię „łańcuchów bloków".
Dobór materiału. Poszukiwania przeprowadzono w bazie Scopus używając pojęć ***:*** *blockchain,* ochrona zdrowia 2017-2019r. Znalezione piśmiennictwo w bazie Google Scholar przeanalizowano pod kątem największej liczby cytowań. Tak wyselekcjonowane piśmiennictwo posłużyło za materiał do opracowania niniejszej pracy.
Wnioski. Trendy w badaniach nad łańcuchami blokowymi w opiece zdrowotnej wskazują, że są one wykorzystywane głównie do wymiany danych, dokumentacji zdrowotnej i kontroli dostępu, rzadziej w przypadku zarządzania łańcuchem dostaw lub zarządzaniem dystrybucją leków.

Słowa kluczowe – *blockchain, system informatyczny, opieka zdrowotna.*

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I. INTRODUCTION

The use of blockchain-based applications (systems) is no longer an unclear vision of the future, but rather medical tool services and specific applications gradually entering the markets. As mentioned in the previous publication, the potential of blockchain technology caused interest of both leading IT corporations and smaller com-

panies in introducing blockchain solutions to the market as a service enabling to build specific applications for the healthcare system. Similarly as in the case of commonly recognized cloud applications (cloud computing, instead of maintaining our own hardware and software resources), where we have Iaas (Infrastructure as a service), PaaS (Platform as a Service) and SaaS (Software as a Service) solutions at our disposal, we can speak of a BaaS (Blockchain as a Service) solution. We can create, test and then practically exploit applications based on block chains based on platforms offered in cloud computing. [1]

The solutions most frequently advocated and developed nowadays for health care include:

- electronic health record - application of the technology of dispersed registers will make it possible to create one, time-ordered, secured patient record. such a decentralised record would contain medical data on the state of health and all diagnostic and therapeutic procedures,
- verification and authorisation of telemedicine services,
- surveillance and traceability systems for the supply chain for medical products and for prescriptive use,
- personalisation of treatment and medical care,
- systems managing and controlling patient's consent, insurance and authorization, and settlement of health services. [1]

In the current medical records (paper, electronic, mixed), it is the patient who is somehow obliged to store the records and deliver them to selected entities. Despite the fact that in Poland there is an obligation to keep records by medical entities, a patient who changes his or her specialist must take a copy of his or her records and hand them over to another doctor. Additionally, currently, both in the case of paper and digital records, the patient does not know who had access to his or her data and what information he or she may have changed.

In some cases, the solution can be found in blockchain technology. First of all, despite the dispersed data registers after entering the system (logging in and authorization), the patient sees all his data and can manage it. The patient decides which medical institution and what data he or she will receive from the health record (e.g. the dermatologist will not see information about the patient's orthopaedic injuries, unless he or she asks for such access). Additionally, the durability of data in the chain of blocks results from the fact that the data entered into it are copied to each node (participant) of the system, thanks to which it is impossible to create points of failure and there is no need to create safeguards in case of damage to a part of the system. Another advantage is that registers based on blockchain technologies eliminate the situation where users (e.g. medical entities) can create many of the same entries - e.g. about patients or medical services - which makes it unnecessary for the supervisory authority to supervise such situations. Importantly, it is also possible to use anonymised patient data for statistical purposes in real time. [2]

The challenges to be tackled are primarily legislative and organisational. Starting with the latter, blockchain technology has so far been less efficient than standard centralised systems. Mainly because the system is able to carry out fewer electronic processes in a time unit, because each blockchain network participant has to approve changes in blocks, and in the case of a centralised system, only one entity is responsible for this, which significantly reduces this time. There are also a number of problems faced by standard IT systems, such as compliance with a high level of security due to particularly sensitive (medical) data, data diversity hampering the transfer and storage of information, or the need to create intuitive software for users (patients and physicians). Legislative issues concern primarily the security of patient data in the context of the Regulation on the Protection of Personal Data (RODO). [2]

II.PROPOSALS FOR SOLUTIONS AND EXAMPLES OF BLOCKCHAIN APPLICATIONS AT DIFFERENT LEVELS OF HEALTHCARE

Durable medical data carrier function

It is estimated that block technology will be used more quickly in healthcare if it is more specific, e.g. limited to the function of a durable data carrier. Blockchain data cannot be changed or deleted, which can bring many benefits to institutions carrying out audits, as it provides high quality evidence about the functioning of the facility. [2,3]

The example system consists of three main elements: Registration Entity, Private Access Entity and Blockchain. The RE is intended to act as an authentication platform (confirming identification) for participants. Users (patient, doctor) log into the system with an individually assigned identification number (ID) and password, thus gaining access to a secure channel for sharing their data. Both sides of the system (sending and receiving data) are able to communicate with the Private Access Unit. This secured channel is required for interaction with the recording unit, as it is possible to send and receive data from the blockchain structure via the Private Access Unit. The term encrypted data means information that has previously been checked for authenticity (to exclude falsification or errors by an algorithm) and subjected to encryption methods to secure it properly. Encrypted (encrypted) data cannot be read outside the system. However, the block code can be understood as a unique address for the location of information in the system. Each block has its own individual code. The block code holder, after earlier identification in

the system is able to obtain coded data assigned to the code. In addition, the block code can be passed on to another person outside the system channels. [3]

The example system is characterized by several solutions. Well, no entity will be able to identify a particular page of the system, even on the basis of captured data it is impossible to check who they belong to. Only authorised (pre-registered) persons will be able to store data and interact with the system and its users. The parties will maintain their individual block code, without which no one is able to interact with the block (and the data stored on it). Even registered users will not be able to obtain private information from other process pages. Additionally, in terms of security, only encrypted data will be stored in the system. [3]

Managing access to medical records and health data

Health data are dynamic and constantly expanding. Because of this, duplicating all the health data for each member of the blockyain network would, according to some researchers, require a lot of computational energy, result in unnecessary use of network resources and create data transfer problems. Blockchain could therefore act as a manager to control access to health records and data. [4]
The blockchain solution proposed by Linn *et al.* [4] would be an index to both the patient record and other health data. Each blockchain index number would inform about the location of specific data outside the blockchain system and contain metadata describing specific information (e.g. diagnosis results, cardiology). The index code would contain information about an encrypted user identifier assigned to specific data and a time stamp indicating the date and time of any change in the data. Health and patient record data would be stored outside the blockchain system in a data repository. This space would need to be large enough to store data in a variety of data formats, from images, metadata, sensor lists to medical records. All information stored in the repository would be encrypted and digitally signed to ensure the privacy and authenticity of the information. When new information is stored (changed) in the repository, this process would be properly recorded in the blockchain system. In each case, the patient would be informed that his or her data has been modified in the blockchain. The patient would also have full access to his or her data and control over how it is shared. Additionally, he could grant (or revoke) access privileges and determine who can search and save information through his block chain in his documentation. [4]

III.EXAMPLES OF NATIONAL SOLUTIONS

The interest in the use of blockchain technology in health care is still growing, as indicated by the literature review [5-7] and the following examples.

Estonia

In a way, Estonia was the pioneer of technologies of key importance for the creation of the national block infrastructure. Since 2012 Estonia uses block chain technology to secure healthcare data and transactions, including 95% of health data in electronic form. All healthcare bills in Estonia are electronically billed and 99% of prescriptions are digitised. [8]

United States of America

Since 2018, one of MedRec's award-winning projects in Boston has been implemented and is still being expanded. This proposal from the Massachusetts Institute of Technology's computer lab includes linking medical records with viewing privileges and data retrieval instructions for external databases, and thus using a block chain to record patient-supplier interactions through intelligent contracts. Once a physician has created a record, it is verified and the patient authorizes the record to be viewed. The party receiving new information receives automatic notification and a shortened indicator of new medical records, and its rights are stored in a chain of blocks. So far, the system has proved to be effective in the areas of drug management, blood tests, vaccinations and other therapeutic interventions. [6]

Sweden

The CareChain Consortium, founded in 2017, is a Swedish blockchain initiative to implement a national health system that enables citizens to regain control of their health data. All national stakeholders are working together to develop a blockchain solution, rather than getting a ready-to-use technical architecture. CareChain tests and progressively improves architecture by working with research centres, medical centres, public institutions, private companies, etc., to develop and improve the architecture. The result is a framework that includes services and tools that could be provided by private companies in the future. The development of a tool for proper identity management of all network participants has proved to be crucial. Having an indisputable public identity is a basic prerequisite for

the legal exchange of data, access to services, authorisation of transactions, etc. It is also essential to have a clear public identity. In order to achieve this, CareChain relies on the latest trend in digital identity, namely self-sovereign identity, i.e. an identity fully controlled by an individual or organisation, without additional intermediation. In order to implement such a system, the consortium uses open source technology. [9]

EU and Polish initiatives in the area of blockchain

The Blockchain Parliamentary Technology Team was established on 9 March 2018 and Kryptowalut, whose task is to cooperate with the legal, scientific and business environment, in order to propose legislation allowing for their development in Poland. [10]

In October 2018, the European Parliament (EP), while emphasizing the importance of the subject, adopted a resolution on the technology of a dispersed register and chains of blocks: building confidence in the flows of funds without banking intermediation. In this document, several aspects relating to the health sector are highlighted. It recognises that blockchain technology has the potential to improve the interoperability of electronic medical data, the distribution of medicines and the verification of identity. Additionally, it was indicated that thanks to blockchain, the patient will be able to control their medical data and have access to who had access to their medical records. The nature of the resolution is such that it encourages further research, attempts to develop standards and good practices. [11] Interestingly, since 2016. The EP is funding MyHealthMyData, a platform that uses blockchain technology to collect and share biomedical information between healthcare organizations and individual patients. This includes, among other things, the creation of accounts for storing personal data in the cloud computing, which will be available by default from any electronic device. [8]

IV.CONCLUSIONS

According to M. Hölbl *et al.*, current trends in research on block chains in healthcare indicate that they are mainly used for data exchange, health records and access control, but less so for supply chain management or drug distribution management. In this respect, researchers stress that the high potential for the block chain has not yet been exploited. Most current studies present a framework, architecture or model that uses block chain technology in healthcare. However, technical details of the blockchain elements used, such as the type of blockchain platform, algorithms, blockchain type or the use of smart contracts, are often not provided. In particular, smart contracts could be used more frequently as they allow significant automation of processes. It also highlights the small number of prototype implementation studies or at least some details of the implementation of the components. [7]

A serious problem when implementing block chain technology for medical records is the willingness and preparation of patients to control the process of collecting and sharing data about their health. In this system, access to the collected data is controlled by the patient himself, who decides whether a given medical entity may have access to them and to what extent (e.g. only data related to orthopaedic injuries, or excluding the history of infectious diseases). It also makes it possible to share anonymised and aggregated data with research centres. [2]

It is worth mentioning briefly the important issue of standards in health care. In blockchain it will be necessary to use HL7 (Health Level Seven) standards, which provide a framework for the exchange, integration, exchange and retrieval of electronic health information. With the release of HL7 version II, FHIRChain (Fast Health Interoperability Records + Blockchain) was launched, which is a data (clinical) architecture that can be used in a block chain focused on health record management. [12]

Further research is recommended focusing on the costs associated with the implementation of block chain technologies, the ability of system integrators to adapt to changing technology and the ongoing maintenance of systems. [13]

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